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CORRELATION OF THE STRENGTH AND DURABILITY OF SOUTHERN PINE

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Introduction

It has been known for some time that the strength of pine structural timbers is a function of specific gravity (density). About twenty-five years ago Johnson[1] demonstrated by actual tests on longleaf pine (*Pinus palustris*) that there is a regular increase in average strength with an increase in density, and this is especially true where all of the pieces tested are reduced to a standard dryness. He also pointed out that compression endwise tests parallel with the grain give the best indication of the general strength value of the wood.

Since these earlier studies many testing laboratories have continued to establish relations between the physical and mechanical properties of wood. This is especially true of the Forest Products Laboratory maintained by the United States Forest Service and the Purdue University Laboratory for Testing Materials. The results of the tests made by the Forest Service and others were discussed by Betts[2] before the American Society for Testing Materials, and rules for grad-

[1] Johnson, J. B. Timber physics. Investigations on longleaf pine. 4. Results on mechanical tests. U. S. Dept. Agr., For. Div. Bul. 8: 22–31. *f. 11–16.* 1893.

[2] Betts, H. S. Discussion of the proposed Forest Service rules for grading the strength of southern pine structural timbers. Proc. Am. Soc. for Testing Materials 15[1]: 369–384. *f. 1–9.* 1915.

ing the strength of southern pine structural timbers based on these various investigations were proposed. In general, these tests showed that as the density increases, the strength also increases in a uniform manner, and the density can be estimated by making use of the proportion of summer wood to spring wood in the annual rings. As the density is dependent on the summer wood, the percentage of summer wood is an index of weight and strength, and is an important guide in judging the quality of timber, independent of any defects it may contain. Tests made on pieces of summer wood and spring wood whittled out separately from broad rings of loblolly pine show that the strength and density of the summer wood is very close to double that of the spring wood. Thus there is a definite relation between strength and density of pine timbers.

In a recent paper the writer[1] reported results of experiments in which some important physical properties of southern pine woods were correlated with the decay induced by *Lenzites saepiaria*. Some of these results show that the specific gravity (density) of the wood materially influences resistance to decay of the heart-wood, the more dense pieces being more durable. By the correlation of the function which specific gravity of wood has thus been shown to play in its strength and durability, one would naturally conclude that when a timber possesses properties to make it strong, the chances are that it will be correspondingly durable. Although such inferences might be made, it was thought well to report the results of studies made on the resistance to fungous decay of timbers which had actually been tested for strength. The results of these experiments are reported below.

Methods of Experimentation

Twelve samples each of longleaf pine (*Pinus palustris*) and shortleaf pine (*Pinus echinata*) were procured, the longleaf pine from the Industrial Lumber Company, Elizabeth,

[1] Zeller, S. M. Studies in the physiology of the fungi. III. Physical properties of wood in relation to decay induced by Lenzites saepiaria Fries. Ann. Mo. Bot. Gard. 4 : 93–164. *pl. 9–13. f. 1. Charts I–XI.* 1917.

Louisiana, and the shortleaf pine from the Missouri Land and Lumber Company, West Eminence, Missouri. All of the samples were 4×4 inches, and each was sawed into two pieces, one of which was sent to the Laboratory for Testing Materials at Purdue University, and the other one retained for use in the preparation of culture blocks. The shortleaf pine samples were numbers 46–57, and the longleaf pine, 58–69, the cross-sections being shown in plates 7 and 8, respectively. The same methods of labeling culture blocks, kiln-drying, taking volumes, etc., were used here as were previously reported.[1] In this work the culture blocks were 1×1×2 inches. Four columns, A, B, C, and D, of five blocks each were used. The position of these in the original samples is shown in the plates.

The culture blocks were placed on end in wide-mouthed quart jars containing about one inch of pine sawdust. Then sawdust was loosely packed around the blocks and moistened with distilled water. The jars were plugged and sterilized as usual, and then the cultures were inoculated with *Lenzites saepiaria.* In this condition they were incubated for 6 months at room temperature. After this time it was apparent that they were not doing as well as in previous experiments where the blocks were not placed in sawdust, and the blocks were therefore removed, piled loosely in a clean pine box, and each layer inoculated anew with *Lenzites saepiaria* grown on pine sawdust. The whole was covered with a layer of damp sawdust which was slightly moistened from time to time. This box was stored in a humid rotting-pit for one year, making a total incubation period of 18 months. After this the blocks were removed, dried and weighed, and the percentage loss in weight during incubation is the index of decay used in plotting the curves shown in figs. 1, 2, and 3.

Strength Tests

A portion from each of the original samples was tested for strength at the Laboratory for Testing Materials, Purdue University. One specimen 6 inches in length from each 4×4-

[1] Zeller, S. M. *Loc. cit.* p. 102.

inch piece was soaked in water for a period of nine weeks. Another specimen 6 inches in length was cut into two sets of four smaller test pieces approximately $1\frac{7}{8} \times 1\frac{7}{8} \times 3$ inches. One of these sets of smaller test specimens, comprising an entire cross-section of the original piece, was stored in wet shavings for a period of nine weeks. The other set was allowed to come to as uniform a moisture content as possible when stored in ordinary outside air, these being later referred to as air-dry specimens.

All specimens were tested by compression pressure endwise, the load being applied in a direction parallel to the grain of the wood. The maximum crushing load was obtained in each case and is given in table I. The moisture content of all specimens was obtained by drying to a constant weight at approximately 210° F.

In the small wet blocks the moisture had thoroughly permeated the wood fiber, and the strength was more nearly coincident with the intrinsic strength of the timber as would have been given by tests of the specimens in a green condition. It also seems that the tests of the wet blocks are more indicative of the intrinsic strength of the wood, inasmuch as the air-dry pieces have non-uniform moisture distribution under the same atmospheric conditions. This condition would apply also to the absorption of water, except that the time of absorption was long enough to bring all of the pieces to a moisture content well above the fiber-saturation point (as shown by the percentage of moisture given in the table), in which case the tests should show the relative intrinsic strength without regard to the varying per cents of moisture as given.

Table I gives the results of both the decay and strength tests. The average percentage loss in weight due to decay was made on the number of heart-wood culture blocks from each sample. There was not enough sap-wood in the samples to be of use in drawing conclusions, thus the results reported here are based on heart-wood alone. However, in previous work[1] it has been shown that sap-wood decays irrespective

[1] Zeller, S. M. *Loc. cit.*

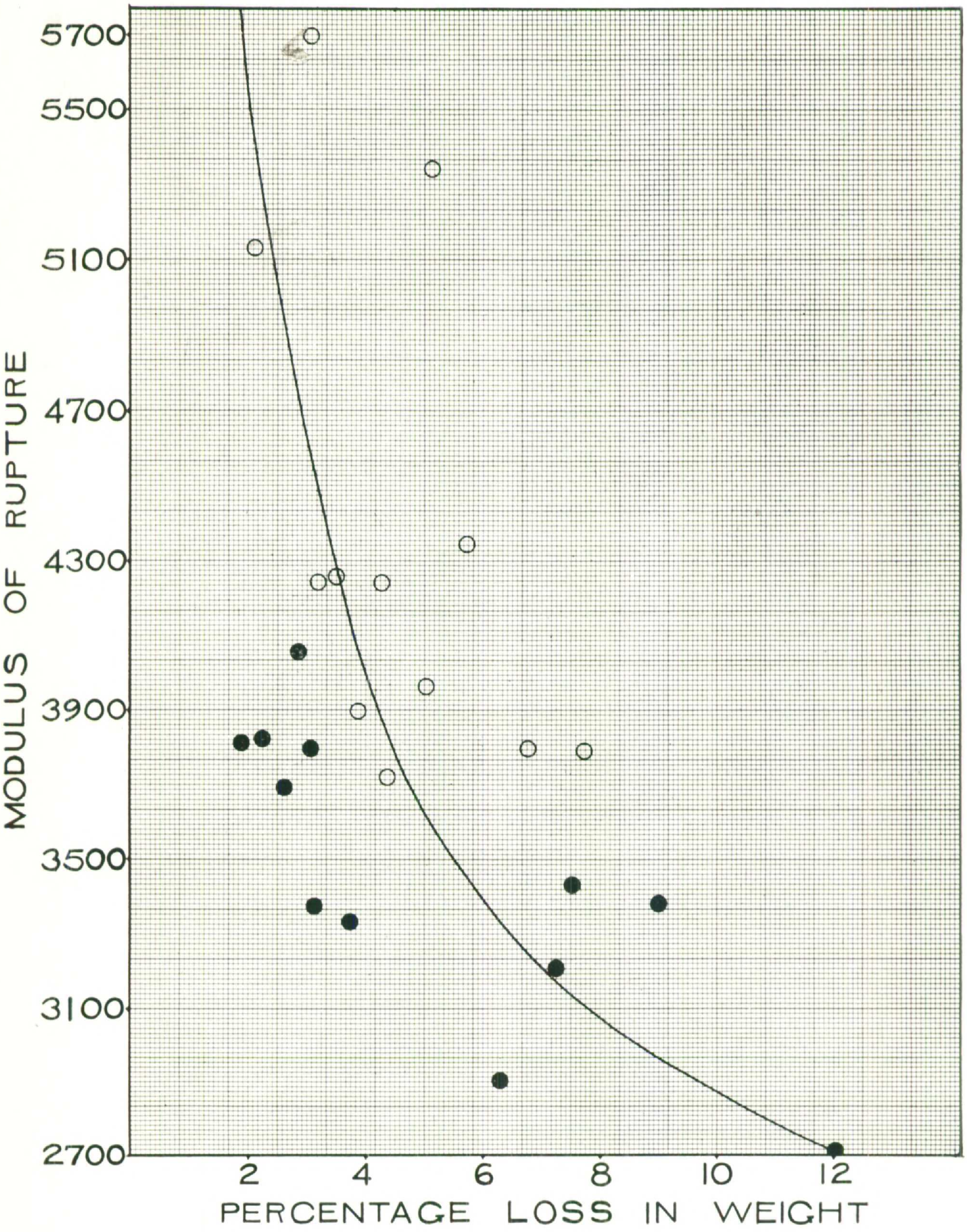

Fig. 1. Showing the relation between strength (when $1\frac{7}{8} \times 1\frac{7}{8}$-inch water-saturated blocks were tested) and percentage loss in weight due to the decay of longleaf (○) and shortleaf (●) pine.

of specific gravity or high percentage of summer wood, factors which function in the strength of the pieces.

TABLE I

STRENGTH AND DURABILITY OF SOUTHERN PINE HEART-WOOD

Sample number	Average per cent loss in weight of heart-wood due to decay	Strength tests					
		Small blocks (wet)		Full-size blocks (wet)		Small blocks (dry)	
		Strength in pounds per square inch	Per cent moisture	Strength in pounds per square inch	Per cent moisture	Strength in pounds per square inch	Per cent moisture
Shortleaf pine (*Pinus echinata*)							
46	3.13	3375	58.1	3050	50.7	6052	10.8
47	7.24	3207	63.8	2840	47.8	5080	12.8
48	2.85	4055	61.9	3655	47.4	5765	12.6
49	9.00	3380	47.5	3065	46.3	5962	10.4
50	7.52	3432	55.9	3550	53.9	6447	11.9
51	3.74	3332	40.1	3185	59.1	5605	11.1
52	2.24	3822	50.0	3770	45.4	7277	10.2
53	1.88	3812	50.7	3410	50.1	6142	11.3
54	12.02	2705	82.3	2440	43.6	3957	15.9
55	2.61	3692	67.5	3555	53.8	6160	14.0
56	6.29	2902	79.9	2790	54.0	5202	12.1
57	3.07	3795	56.9	3910	43.6	5817	13.8
Longleaf pine (*Pinus palustris*)							
58	2.11	5130	25.2	5220	25.3	8032	13.5
59	3.19	4255	50.7	4290	41.3	7312	13.1
60	5.12	5340	26.0	5270	24.0	8812	10.6
61	5.72	4342	65.6	3990	58.4	7012	14.5
62	4.26	4240	67.1	4180	53.9	7817	13.5
63	3.06	5695	42.0	5540	40.2	8272	14.0
64	4.37	3720	57.7	3570	47.3	6635	13.1
65	6.76	3795	60.0	3690	56.1	6450	12.3
66	7.73	3790	81.6	4020	64.6	6467	13.7
67	3.50	4257	44.1	4130	39.6	7485	11.2
68	3.87	3897	43.4	3890	45.7	6897	10.3
69	5.03	3962	42.4	3910	46.1	7147	11.3

Results and Conclusions

The curves in figs. 1, 2, and 3 graphically represent the results presented in table I. Figure 1 shows the relation between strength and durability of pine heart-wood when the strength tests were made on $1\frac{7}{8}\times1\frac{7}{8}$-inch water-saturated blocks. Figures 2 and 3 show the same relation when 4×4-inch water-saturated blocks and $1\frac{7}{8}\times1\frac{7}{8}$-inch air-dry blocks, respectively, were tested for strength. The three strongest samples, 63, 60, and 58, show considerable loss in weight, which is not totally due to decay. They were highly resinous,

and some of the resin was lost in sterilizing under steam pressure. The curves are corrected for this error.

The curves in the three cases show that as the strength increases the durability increases. In order to refer to some specific instances, examine plate 7, showing the cross-sections of the original shortleaf pine samples, and notice numbers 48 and 53 in contrast with numbers 49 and 54. The former show a much higher percentage of dark summer wood and somewhat narrower growth rings in the heart-wood than in the latter. In the table, numbers 48 and 53 show a loss in weight due to decay of 2.85 and 1.88 per cent, respectively, and are relatively strong, while numbers 49 and 54 show a loss in weight from decay of 9 and 12.02 per cent, respectively, and are not nearly so strong as numbers 48 and 53. Other examples, such as contrasting numbers 46 with 56, 52 with 47, etc., will show this same relation of strength and decay. For instance, in plate 8, showing the original samples of longleaf pine, number 63 has narrow rings with a high percentage of summer wood, characters which are conducive to strength, in contrast to number 65, which has broad rings with a low percentage of summer wood. The strength tests show number 63 much stronger than 65, and the decay tests show a loss of 6.76 per cent in number 65 and 3.06 per cent in number 63. The same relation is shown when contrasting numbers 58 with 61, 59 with 64, 60 with 66, etc.

The results thus show that whether we are dealing with shortleaf pine or longleaf pine the stronger pieces of heartwood are the more durable, and *vice versa.* This, however, does not apply to sap-wood, as it seems to decay irrespective of the amount of summer wood and specific gravity, which materially influence the strength of yellow pine sap-wood.

The writer wishes to express his appreciation to the Missouri Botanical Garden for the use of the laboratories; to the Southern Pine Association for providing funds which made this work possible; and to Dr. Hermann von Schrenk for suggesting this work and for his aid and interest.

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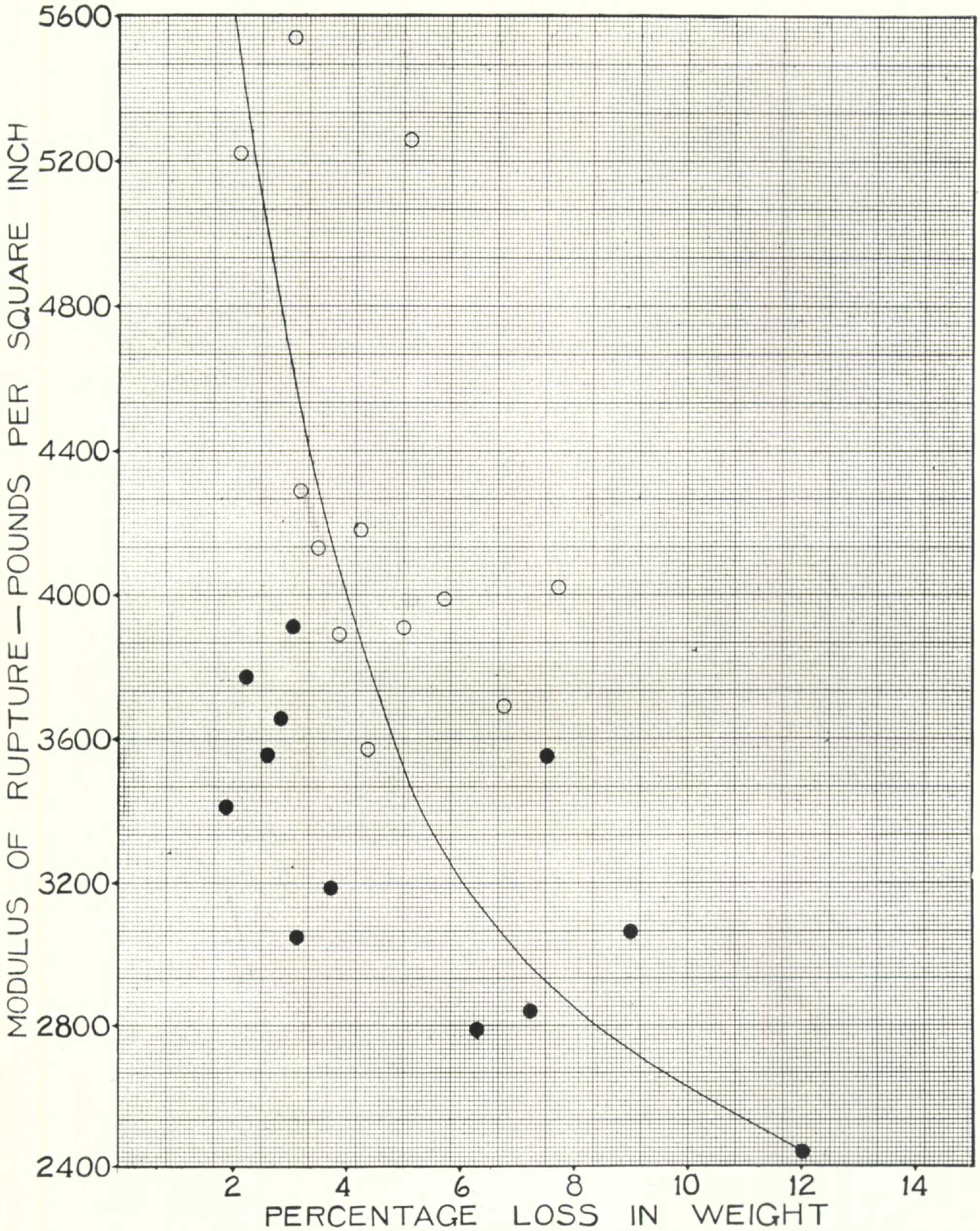

Fig. 2. Showing the relation between strength (when 4×4-inch water-saturated blocks were tested) and percentage loss in weight due to the decay of longleaf (○) and shortleaf (●) pine.

Fig. 3. Showing the relation between strength (when 1⅞×1⅞-inch air-dry blocks were tested) and the percentage loss in weight due to the decay of longleaf (○) and shortleaf (●) pine.

Explanation of Plate

PLATE 7

The original samples of shortleaf pine (*Pinus echinata*). The lettered squares are 1×1 inch and represent the columns of culture blocks used in the experiments.